Baryonic Oscillation Spectroscopic Suvery at Brookhaven

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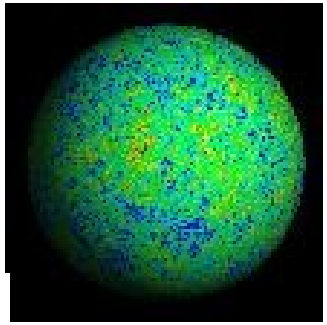
BROOKHAVEN
NATIONAL LABORATORY

Outline of the talk

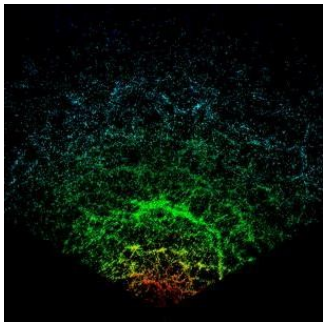
- Brief introduction to cosmology and why it matters
- BOSS experiment and our involvement with it
- What will we be doing in the next decade

History of modern cosmology

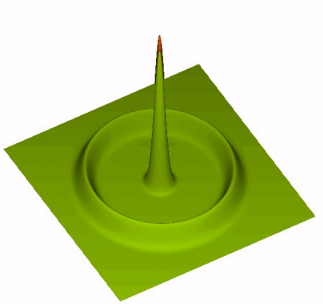
- 1923: Friedman's solutions to Einstein's eq.
- 1929: Hubble discovers Universe's expansion
- 1967: Penzias & Wilson discover Cosmic Microwave Background (CMB)
- 1991: COBE measures CMB fluctuations
- 1998: Evidence for accelerated expansion from SNIa
- 2003: Standard Cosmological model emerges



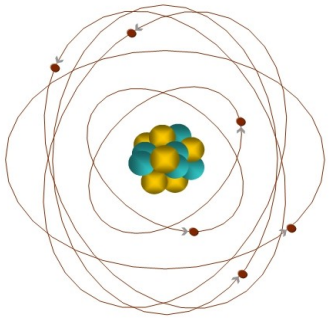
Cosmic Microwave Background



Galaxy distribution

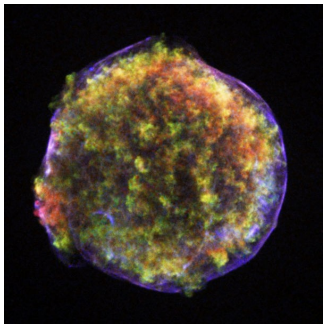


Baryonic Acustic Oscillations

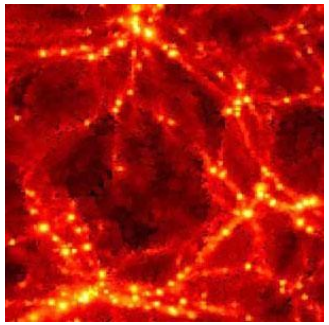


Big Bang Nucleosynthesis

DATA

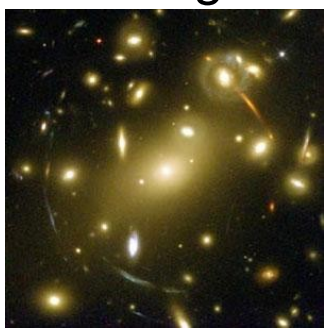


Supernovae Ia

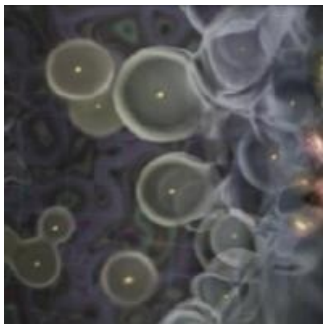


Lyman-alpha forest

Gravitational lensing

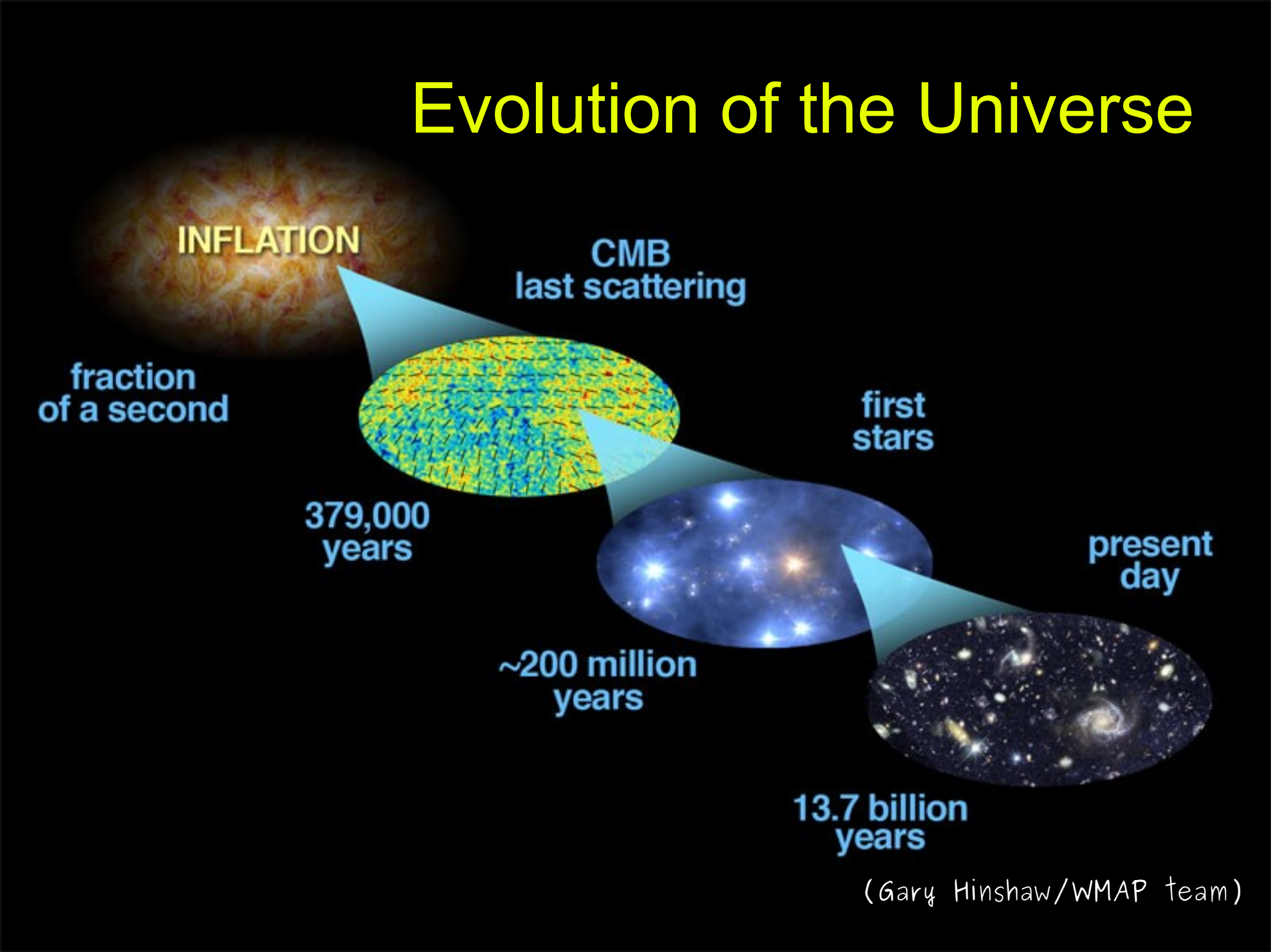


Clusters of galaxies



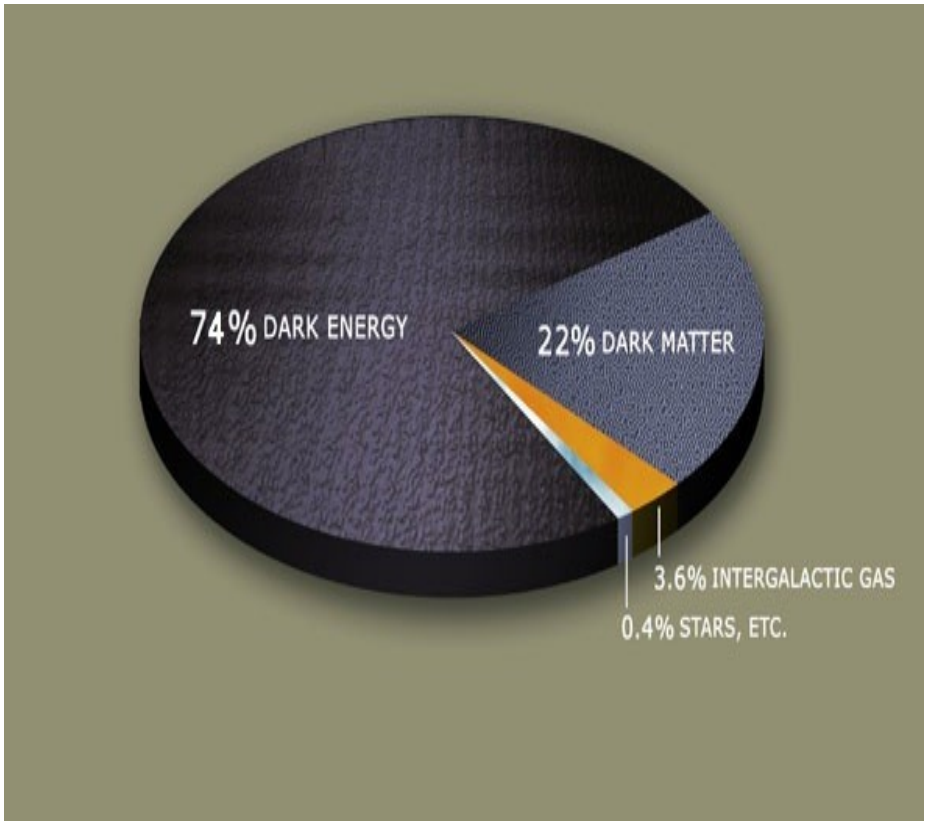
Neutral hydrogen tomography

Evolution of the Universe



(Gary Hinshaw/WMAP team)

The Dark Sector



- Well defined stress-energy tensor
- Dark matter:
  - cold
  - pressureless,
  - very weakly or non-interacting
- Dark energy:
  - Vacuum energy or equivalently
  - fluid with EOS $p=-\rho$

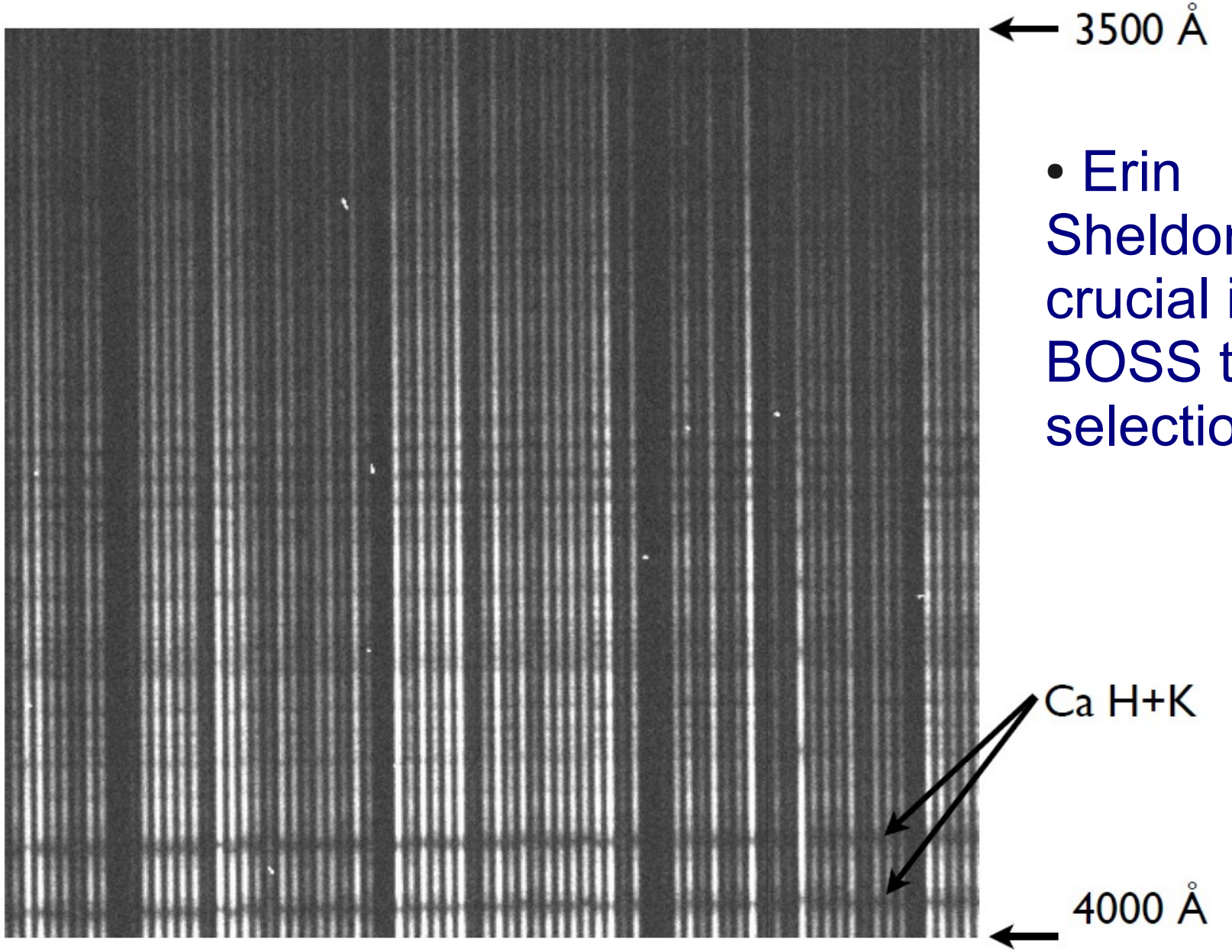
Standard cosmological model

- General macroscopic picture well understood
- The microscopic picture and relation to the fundamental physics remain to be understood:
  - What is the nature of dark matter?
  - What is the nature of dark energy?
  - How does the dark sector fits with the standard model of particle physics
  - Does gravity obey general relativity on all scales and at all energies?
  - Is inflation an accurate description of the early universe?

BOSS

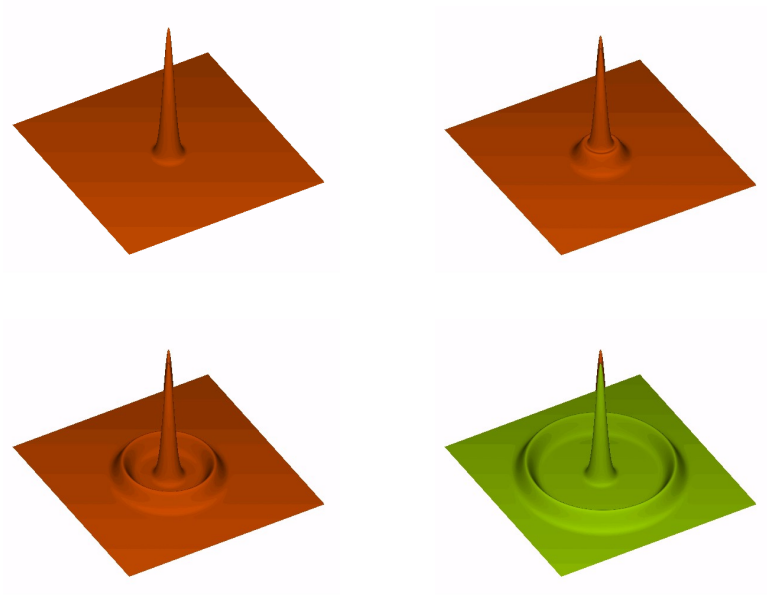
- Dark time observations on 2.5m SDSS telescope
- Fall 2009 – Spring 2014
- 1,000-fiber mid resolution UV-NIR spectrograph
- Redshifts of 1.5 million luminous galaxies to $z = 0.7$ over 10000 square degrees
- Lyman-α forest spectra of 160,000 quasars at redshifts $2.2 < z < 3$
- **Perfectly on schedule so far**

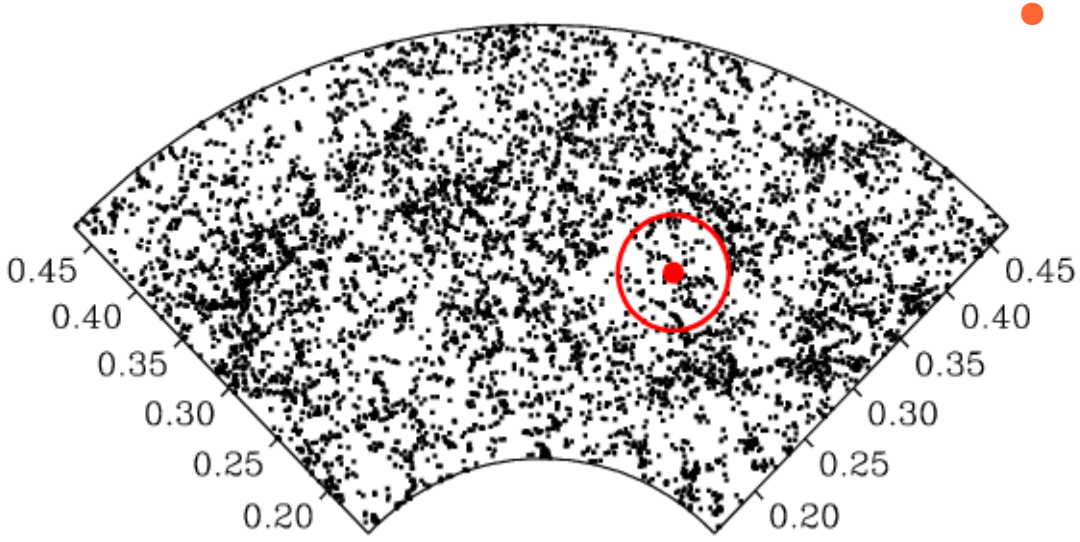
BOSS first light on sky (Aug 28 09)



- Erin Sheldon crucial in BOSS target selection.

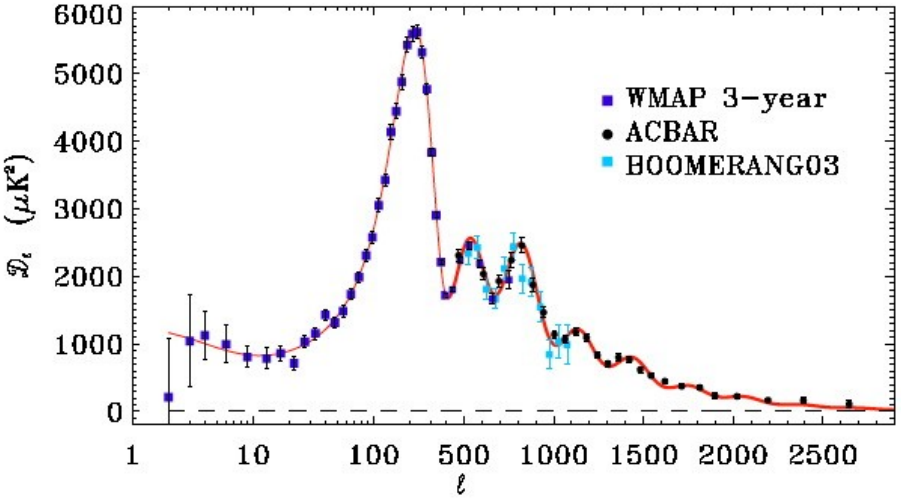
Baryonic acoustic oscillations



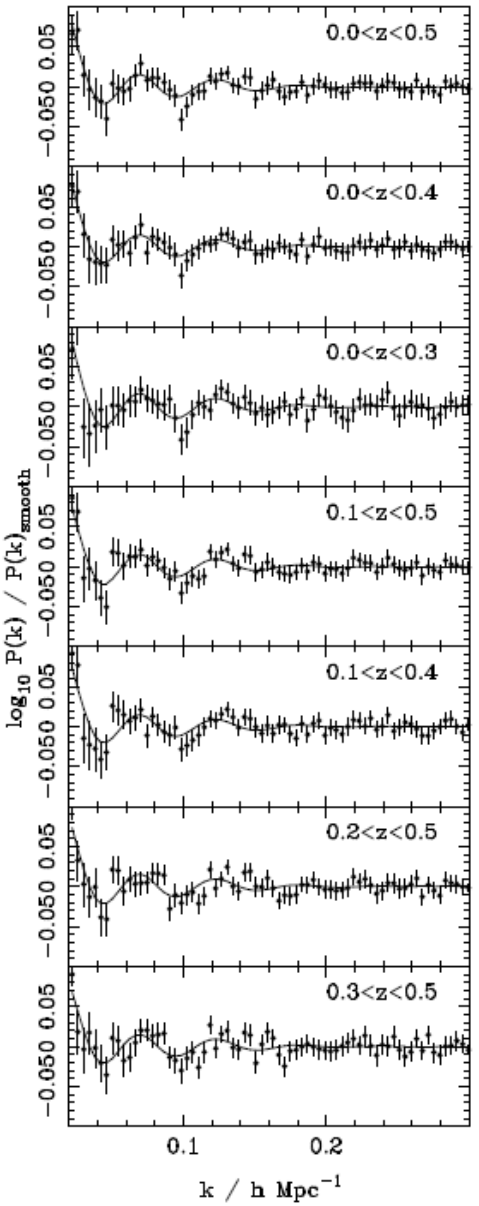


- Before decoupling of baryons and photons, plasma can support acoustic waves
- These imprint a characteristic scale into the correlation properties of dark matter

Baryonic acoustic oscillations



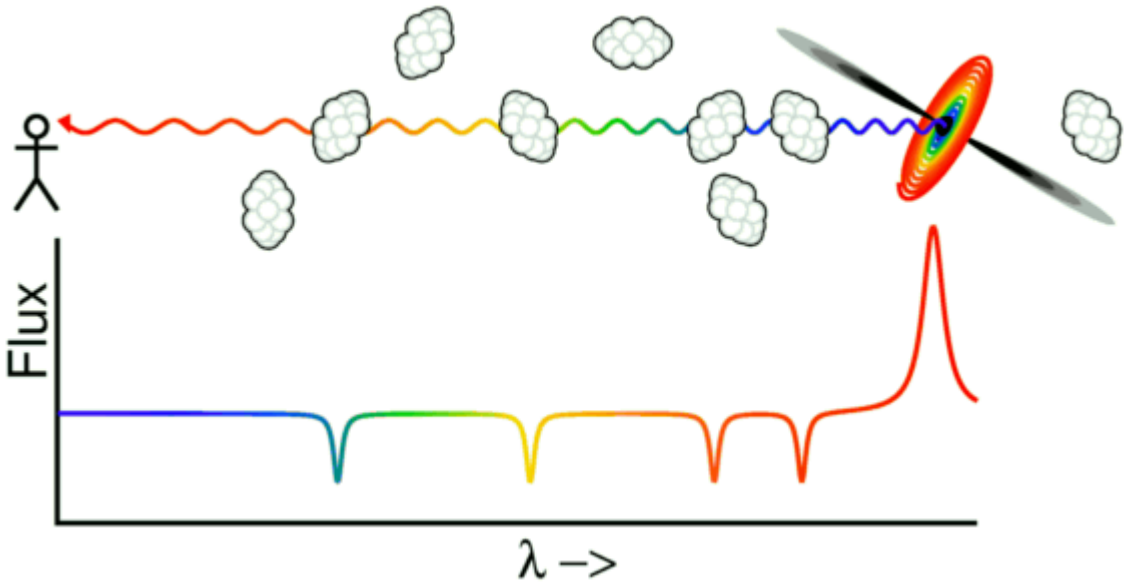
SDSS + 2dF data



- The same oscillations that can be seen in the Cosmic Microwave Background, can also be seen in galaxies
- They are a standard rod allowing measurements of the expansion history

Lyman-alpha forest

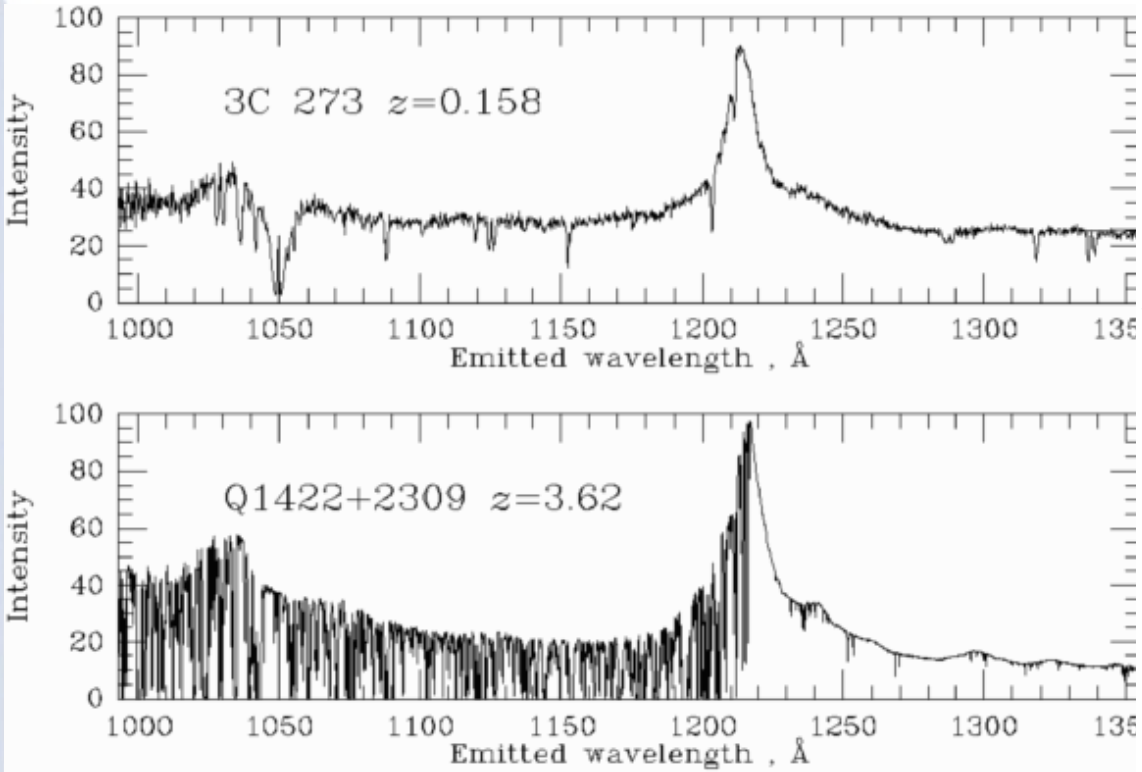
- clouds of hydrogen absorb light from distant quasars, blueward of Lyman-alpha emission

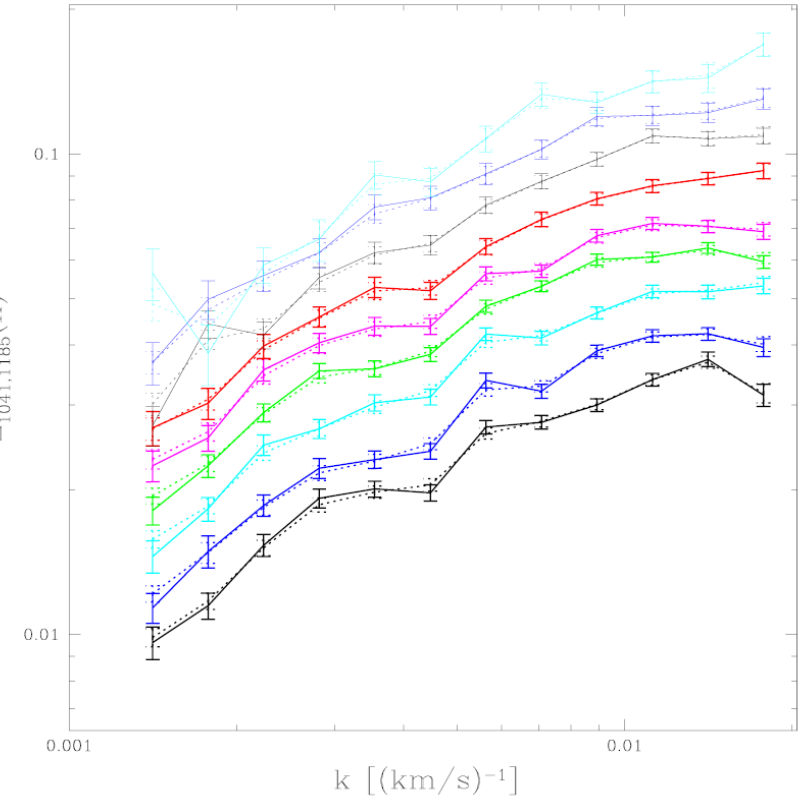


- Traces neutral gas (around 1%)
- Small fluctuations are easy to model

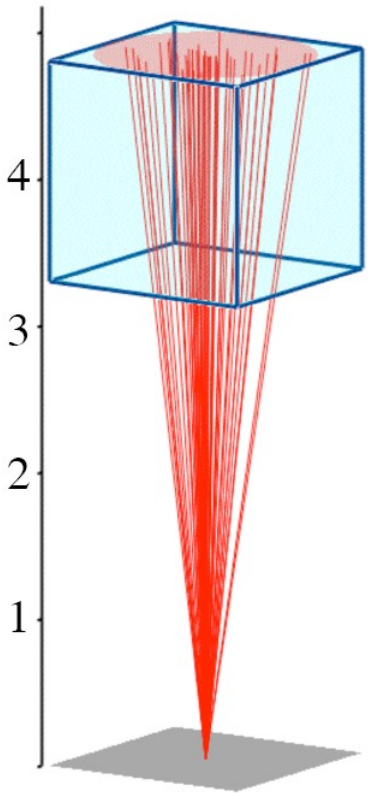
Lyman-alpha forest

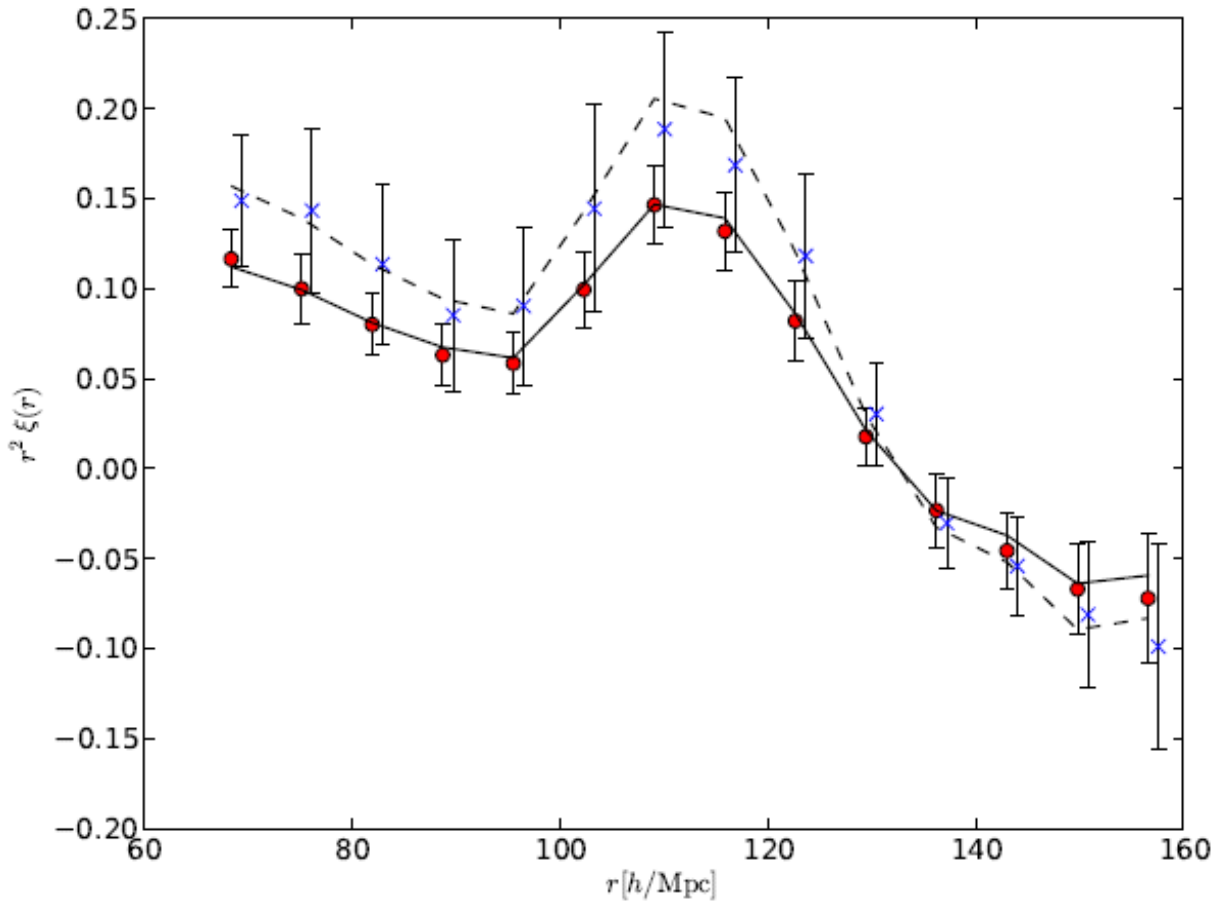
- clouds of hydrogen absorb light from distant quasars, blueward of Lyman-alpha emission





BAO with Lyman-alpha forest



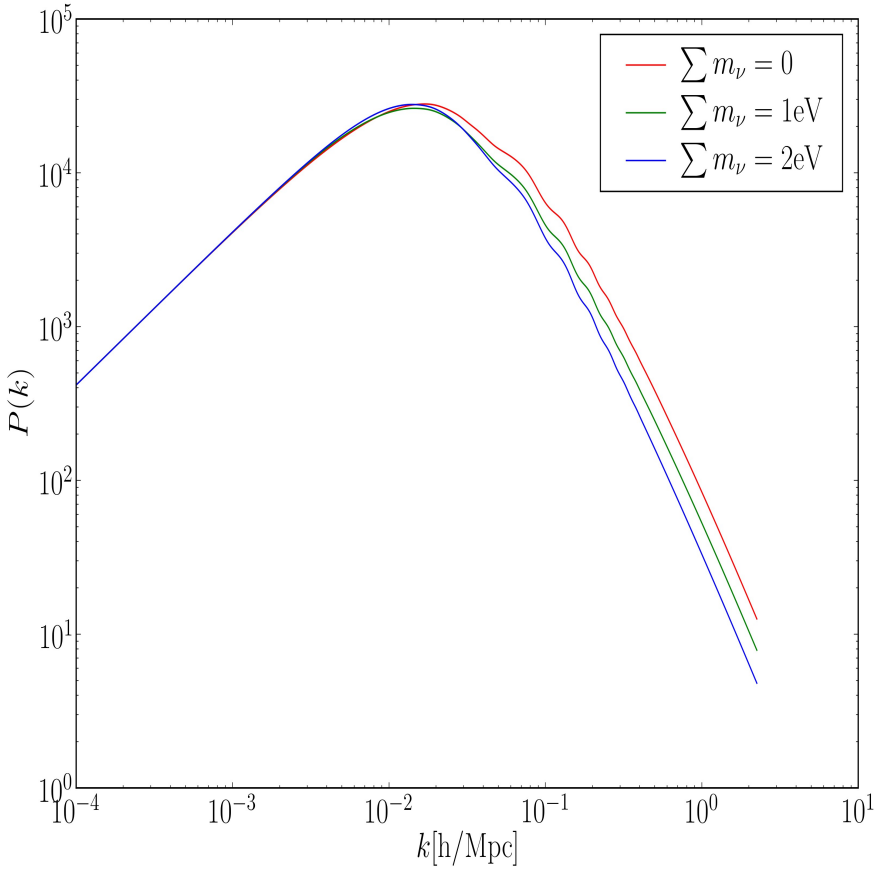


- Simulations indicate that it should work

BAO with Lyman-alpha forest

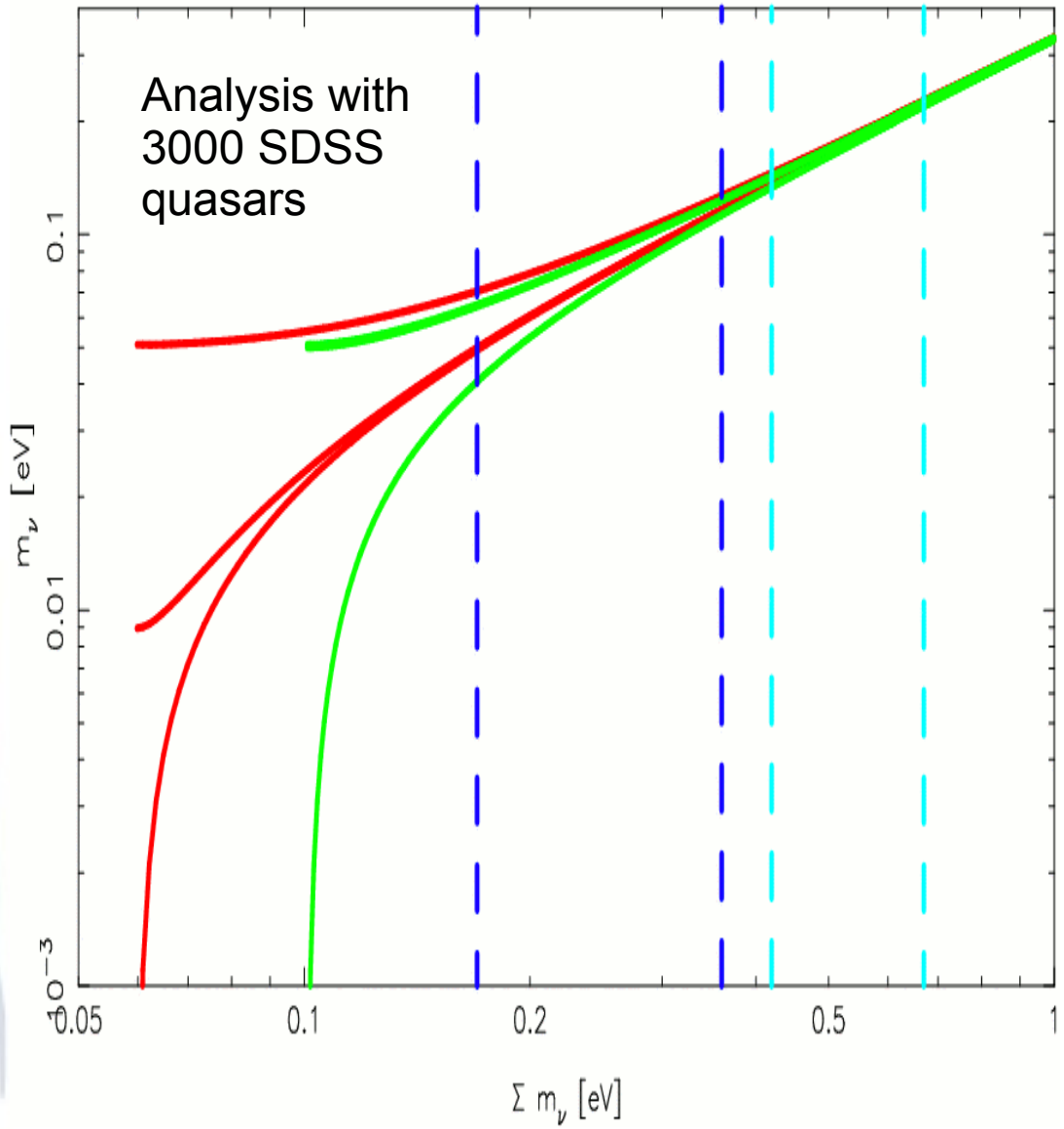
- BAO with Lyman-alpha is one of the key projects of the BOSS experiment: to determine the BAO scale at z=2.5 with 1.5% accuracy.
- First detection of signal correlation across quasar sightlines by early 2010 from BOSS commissioning data
- First cosmological analysis by 2011, to be refined at a later date

Neutrinos with cosmology



- Neutrinos produce a characteristic scale in the power spectrum of matter fluctuations
- Sensitive to absolute neutrino mass
- Measurements from galaxy clustering and Lyman-alpha forest can be very competitive

Neutrinos with cosmology



- BOSS can measure neutrinos via galaxy distribution AND Lyman-alpha
- Galaxies and Lyman-alpha have different systematics

Neutrinos with BOSS

- From galaxies:
  - Simulations with neutrinos and painted galaxies
  - Analysis of galaxy power spectrum
- From Lyman-alpha:
  - Much more difficult than BAO
  - Need better, bigger simulations
- Can realistically expect to be able to distinguish between normal and inverted hierarchy

BigBOSS

- Stage IV dark energy expt
- Complementary to LSST
- Spectra of 30 mil galaxies, 1 mil quasars
- ~5% of the entire observable Universe
- **BNL will remain flexible to respond to these developments**

Large Synoptic Survey Telescope (LSST)

- Wide, fast, deep
- 3.2 Gpix camera on 8m telescope
- Rapid scanning of the entire sky in 6 bands
- Dark energy cosmology through all four JDEM methods: weak lensing, BAO, supernovae Ia, galaxy clusters